EFFECTS OF ECOLOGY ON TECHNOLOGICAL CHANGE

by Robert F. Scott

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Effects of Ecology on Technological Change u.

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The title of these remarks deliberately reverses the usual perspective. To make it more explicit, I could add a sub-title: "Can Ecology Solve Our Environmental Problems?"

We have heard of man and his ecological relationships; we will be hearing of the basically political actions he does or does not take in this context. I will examine the area between these two views, and ask: With what effect is "ecology" as a discipline, body of knowledge, and operational perspective capable of influencing technological change, the latter taken to include all the environmental impacts of accelerating "development."

You have heard the story of the airliner pilot who announces to his passengers that they are hopelessly lost, but then adds the reassurance that they are making record speed.

I selected this story because I want to allude to the good environmental news, in the midst of the continuing stream of bad. I see it is also an unfortunate commentary on our general situation as well. One could even invoke the "Peter Principal" -- the new tongue-in-cheek theory that people eventually rise to their level of incompetence. It may turn out that our civilization has reached that level.

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There is good news, however, and it could include any of several decisions that have recently been made; each with a perception of ecological principals, scientific evidence, or human values as a strong ingredient.

As examples, let me just list the following:

--An innovative and complex agreement now being negotiated between the Federal Government and a specially-created water district in California that would provide water at greatly reduced prices so long as the privately-owned acreages involved are managed in such a way as to provide needed habitat for migratory birds.

--An agreement that pipeline companies go around a Gulf Coast National Wildlife Refuge, rather than taking a least-cost route across the marshes.

--A decision by an executive board of the State of Florida to curb dredge and fill operations along its shores.

--The decision by the legislature and Governor of California to continue the special controls which may yet accomplish what the unprecedented public outcry called for: "Save San Francisco Bay."

--And last, but not least, the recent decisions to curb the use of DDT and other persistent pesticides, announced by several States and even more recently by the Department of Agriculture itself.

These encouraging developments do not, in themselves, represent new scientific data. They are decisions. They began as raw facts, became perceptions, then acquired meaning. Then, through analysis and

social decision processes, they became, we hope, a little better reflection of the general public interest. How far does ecology, or should ecologists, permeate this stream of events?

First of all, one thing is certain: Ecology is bustin' out all over!

It is bustin' out so fast, and so all over, that I'm sure today's news includes still more evidence. Time magazine (1) has already proclaimed: "It is...the year of ecology."

I remember the first time I saw "ecology" as the subject of a newspaper editorial in The Washington Post just a few years ago. I've since heard the theme echoed in all the news media--as well as on Capitol Hill, as you know. Within the last few weeks Life magazine treated the subject in a full page editorial, Time inaugurated a new weekly department called "Environment," and the August 15 issue carried a long piece featuring ecology and ecologists. A recent issue of Look magazine also featured the improbable juxtaposition of folk singer Pete Seeger and C.P. Snow essentially speaking out on aspects of the very title of this paper.

To the naive, ecology may seem to be just another science-based "fix" which has been waiting in the wings all along, ready to materialize on cue and miraculously solve a new batch of human problems--as technology has ostensibly been doing for so long. To others, ecology may even seem like a masked rider on a white horse, who in due time will leave behind a silver bullet as souvenir of another inevitable victory over evil.

There is a real chance that society may come to see the ecologist as saviour and hero. One of our colleagues actually was represented this way in an article in a Hearst magazine aimed at the big-spending hedonist-activist youth market. Some of us make it a point also to read the underground press occasionally, seeing it as a sort of Distant Early Warning indicator of social trends. Here, too, we see that non-conformist youth have recently discovered and adopted ecology as part of their cause and mystique. This is reassuring, but it is at the same time a reproach and put-down to the rest of society. A belief in, and acceptance of, ecological concepts seems to be so at variance with the normal conduct of The Establishment that it fits nicely in the anit-establishment views of radical youth.

It has been said that a fish probably is not aware of the water it swims in. In our case, it appears the fish has come to notice, not only the water, but the quality of the water, and ecology has passed its relevancy tests.

There are good reasons for this. Many articulate scientists, and non-scientists with ecological viewpoints, have, as Time said of Barry Commoner, brought "an ecologist's insight and a polemicist's passion" to the arousal of social concern about the environment and other problems of technological progress. In addition to the "conservation" movement of long standing, the new need to sound the alarm on the population crisis also made, perhaps not strange, but at least unexpected bedfellows of a wide assortment of people. The

arguments on this subject necessarily end up in either theological or ecological terms. (Thus the world has been treated to a crash program of education on the nature and outcome of exponential growth--a fundamental that long eluded many resource policy-making bodies, and even some earlier non-mathematical ecologists. The nature of exponential degradation is still eluding many policy-makers).

What is the exciting promise that has attracted this attention? In simplistic terms, the thinking goes something like this:

A. We do have environmental problems.

B. There is a science, ecology, which deals with environment.

C. Science solves problems.

D. Therefore, ecology will solve our environmental problems.

Q. E. D.

How we wish it were that simple!

Ecology does deserve the attention it is getting, however. The organism-environment orientation was a ready-made introduction to its relevance. Beyond this, the ecosystem has long been a significant integrating concept in science. The nature of ecological thinking encourages a holistic view of natural phenomena; it emphasizes process, change, interrelations; it has a tendency to connect things up, and look at the whole package. As Pete Seeger put it, "You see, everything in the world is tied together." Also, in a world that collects and generates information at a rate that far outstrips its ability to understand or act upon it, there has to be some kind of

holistic integration and synthesis. This alone is a significant contribution from ecology.

Bertram Gross and Michael Springer (2) deserve credit for discovering this bit of poetry:

> *"... Upon this gifted age, in its dark hour*
> *Rains from the sky a meteoric shower*
> *Of facts... they lie unquestioned, uncombined,*
> *Wisdom enough to leach of us of our ill*
> *Is daily spun, but there exists no loom*
> *To weave it into fabric."*
>
> *---Edna St. Vincent Millay*

Ecology may not be the only game in town, but, to many, it is the only loom in sight. And the fabric of ecology emphasizes that you can't do just one thing in an environment. From one view, ecology is, therefore, a kind of science of consequences. A further question is whether it can evolve into a kind of decision science as well.

Actions and reactions, causes and effects have been traced out and described in many a complex ecosystem. Ecology can predict consequences with fair success, if given the chance. This is what many individual ecologists are now publicly doing, and it is what some public policy has provided for in legislation such as the Federal Fish and Wildlife Coordination Act. But here is where we begin to encounter inadequacies. After predicting consequences, then what?

Now we cross a boundary into the realm of good and bad, virtue and evil--intrinsic qualities that are notably absent in ecosystems as biologists view them. Edwin Land of Polaroid once reminded us that in nature there is no such thing as reward or punishment, only consequences. But for man and his problems of technological over-kill, and deteriorating quality of life and environment, there are good and bad, rewards and punishments. The problem for society is to tell one from the other, to select criteria and come to some operational agreement on it.

I used the word quality. This immediately introduces the element that ecology as a pure science does not include--a concept of values, as we think of them. A recent New York Times report commented that "scientists as a group have long disdained direct political action and propagandizing, feeling it compromised their scientific objectivity." But it quoted activist Paul Ehrlich as asking "What am I going to do, crawl under my professional reputation when the bombs start falling--or eat it when we get hungry?"

This overstates, but illustrates the kind of dilemma the Ecological Society of America is struggling with right now. The Society's journal, Ecology, carries the notice that "The pages...are open to papers of ecological interest stressing basic, not applied problems." But the Society itself has developed action-oriented committees, and is currently seeking new ways of becoming socially relevant.

Nevertheless, it seems that what Lord Snow once called critically "The Principal of Maximum Purity" in the value system of science is still going strong, though having difficulties with the motivations of many individual scientists. What is pure in science is getting to be as much of a question as it is in water quality control.

You may have heard a radio commercial, sung in blues style that goes like this:

"Michigan water used to taste like sherry wine
Now Michigan water tastes like turpentine."

If you write Clean Water, Washington, D.C., you can get more information, but I doubt that you can find out what "clean" water is, for this is a value judgment established only by definition and agreement. It does seem strange that pure water can only be defined in terms of the impurities in it. And that, by implication, a pure scientist could measure the impurities but not be qualified, as a scientist, to tell you whether the water was pure. It is the political and economic, not the scientific process, that defines pure water for us.

By analogy, the ecologists seem to be in somewhat the same fix when it comes to quality of the environment, or human tolerance of technological "progress." So long as events in an ecosystem involve objective happenings below the level of what we call consciousness in man--with no hint of external values or purposefulness--they are considered a proper object of scientific study by ecologists. But when

we include an organism, man, that has evolved a function we call reasoning, and therefore introduce purposeful, rational, subjective human choice to our ecosystem we are passing the bounds even of ecology as it has heretofore been considered as a science.

Dorothy Goldberg (3) has found a beautiful commentary on this distinction:

> *"For plant, animal, or star, to live is to have no doubts concerning its own being. None of them has to decide what it will be the next instant. Thus their life is not drama but --- evolution. But man's life is exactly the opposite: it is having to decide every moment what he must do the next moment and, therefore, having to discover the very plan, the very design of his being."*
>
> .....*ORTEGA Y GASSET*

This fundamental seems to be causing a major hang-up for doctrinaire ecology.

This appears to be the case despite the growing, though orphaned, literature in "human ecology." It probably explains why there still are individuals who are equivocal on the question of whether man is a part of, or one who tampers with, ecosystems. It is the subjective, value-laden decision-making that doesn't seem to fit. Even though the fundamental theory of organic evolution is perhaps the outstanding

paradigm of decision processes, ecology tends to trip over its own roots in biology when it comes to viewing man-environment systems and issues in their entirety. A completely holistic and comprehensive view dictates a concern with human value systems and with types of cybernetic and decision processes heretofore not considered to be the proper business of ecologists. Yet this is where the ultimate issues really lie, and here is where the action, if not the insight, is found. Pure scientific information in itself is not enough to solve our environmental problems.

In effect, ecologists might say: All right, man is part of the ecosystem. The broad view of ecology will help describe the effects of what he does, or predict effects of what he may consider doing. We will stand ready, and even become aggressive about supplying basic knowledge. But whether he will or will not do various things is a question for the social sciences and social processes. We will fume and criticize these events beyond the borders of our own science--especially when they involve the witchcraft of the economists with their "dollar values," or the technological interventions of engineers and "do-ers," who build and do things merely because they know how. We will remember Ian McHarg's (4) assurance that "...man is natural, and therefore, there are no divisions between the natural and the social sciences.", and Frank Darling's (5) urging that "Ecology...should face firmly its social destiny."

But we seem to be pushed most often into a role advocating a kind of ideology, in adversary processes where someone is assumed right and

someone is presumed wrong. This is one way of influencing that decision process which so characterizes man's role in the ecosystem. Perhaps it has been the only effective way in many situations so far, but it is a relatively crude and unscientific one. It is also in marked contrast to some of the more sophisticated methods of decision-making which focus on identifying an optimum, rather than a right or wrong; of making deliberate trade-offs of one value for another to best suit the purposes of the decision. These invite consideration of mutual accommodations in the public interest, rather than only the preservation alternatives of the pure protectionist viewpoints that unfortunately tend to be automatically discounted as predictable self-interest--as, of course, are other partisan views in an adversary process.

Suppose that, rather than being a personal political activist, an ecologist does wish to push deeper into the decision process, as a scientist. His first encounter will likely be with economics, a discipline whose name has the same original root as that of the ecologist. The economist is used to allocating in the face of conflicting demands. Lawrence Slobdkin (6) has pointed out that "conflicts of interest do exist with reference to almost all ecological decisions," and added that "The immediate practical problem is that the different, highly competent experts dealing with specific sub-problems of the general problem are honestly not aware of the full ramifications of their own work, and therefore may find themselves acting at cross purposes to each other. I suggest that this situation is dangerous..."

I think it is time that both the economists and the ecologists abandoned their polarized positions which have been separated primarily and unnecessarily by the issue of intangibles and "dollar values." We desperately need to perfect ways of arriving at optimal decisions about the environment and we had better use to the hilt whatever science we have that is capable of handling the problem of values. Economics is one discipline that customarily does this, and I should like to quote some comments on this score from the gospel according to Fritz Machlup, (7) an economist. Aiming at his own colleagues as much as anyone, he says, in part:

> *"...I have noticed a tendency...to make a distinction between economic and noneconomic values....I submit that this is a mistake. We must not put 'economic values' to one side and other values--say, ethical, aesthetic, social, political, or 'human'--to the other side. The economic valuation of benefits and costs of an institution, plan, or activity must attempt to take account of values of any sort and to apply reasoned argument and rational weighting to problems commonly approached only by visceral emoting....the point to note is that economic evaluation is not confined to the items for which price data are available. It comprises all pros and cons of the plan or activity under examination....Quantification of nonmeasurable*

> *values is often necessary for rational decision-making."*

This philosophy matches the holistic view of ecology, and it suggests that the much cussed and discussed procedure of cost/benefit analysis, rather than being the badge of the bureaucracy, and the bane of the ecologist, could turn out to be his best avenue of influence when he learns to use it effectively. John Krutilla (8) and Peter Pearse (9) are among the economists who are already making much progress in this direction.

Life magazine spoke of the "environmental side effects" of the activities of government and industry. This labelling of consequences as "side effects" is the crux of the matter as both ecologists and economists have shown. It is only the choice of framework for analysis that determines whether effects of an action are considered internal to it, or merely external "side effects." The problem is one of somehow taking note of all costs and all benefits, so there will be no "effects" that are "side." The analysis and decision process can then "internalize the externalities", be truly comprehensive in considering the values and trade-offs, and identify who is actually paying, or not paying whom, for what, in the proposed action. It is well to examine who actually gains what, and who loses what, in each case.

Garrett Hardin (10) a natural scientist, describes the issue this way:

"*We want the maximum good per person; but what is good? To one person it is wilderness, to another it is ski lodges for thousands. To one it is estuaries to nourish ducks for hunters to shoot; to another it is factory land. Comparing one good with another is, we usually say, impossible because goods are incommensurable. Incommensurables cannot be compared.*

"*Theoretically this may be true; but in real life incommensurables are commensurable. Only a criterion of judgment and a system of weighting are needed. In nature the criterion is survival. Is it better for a species to be small and hideable, or large and powerful? Natural selection commensurates the incommensurables. The compromise achieved depends on a natural weighting of the values of the variables.*

"*Man must imitate this process. There is no doubt that in fact he already does, but unconsciously. It is when the hidden decisions*

> *are made explicit that the arguments begin. The problem for the years ahead is to work out an acceptable theory of weighting."*

So, we want to make choices explicit, commensurate the incommensurables, and internalize the externalities, among other things, in making and implementing optimal decisions about what happens to man's environment. And we know that ecology should play a role, and that these decisions should concern actions before they happen, rather than just trying to correct newly recognized mistakes.

This will not be easy. Professor Caldwell (11) has reminded us before that, unfortunately, "the environment as a whole is not a public responsibility." Thus, I suspect the single decision to put a man on the moon, by means not then known, was, at the time it was made, operationally more effective than a similar decision today to do right by the environment would be, using knowledge, which, even if not used, is largely available. Going to the moon was a public responsibility. The environment is everyone's and no-one's.

But let us try to look at the problem as all of one piece. Our interests will cover a very broad spectrum, ranging from purity of food, air and water to esthetic concerns with wilderness, urban design and architecture - and we might add that our perspectives must cover an equally broad spectrum, from biological, social and political sciences through ethical and moral matters to even the religious and spiritual.

Let us realize that the whole problem goes right back to a fundamental principle of ecosystems and a great many other natural phenomena--the cybernetic model. Let us stop differentiating between the legitimacy of natural or social science concerns and simply say that we are talking about a recognizable man-environment system. A system. One which should be a cybernetic system. A system that should be characterized by the operation of feedback control mechanisms; by negative feedback that prevents excesses in any direction. But, as we see in reality, a system that is instead obviously out of control, and where positive feedback is the order of the day in many different directions -- especially in population growth and technological developments. As C. P. Snow (12) puts it:

> *"...there is no known example in which technology has been stopped being pushed to the limit. Technology has its own inner dynamic...it would be reassuring to find one case in which technology was called off.... At present we are letting technology ride us as though we had no judgment of our own...the demon of progress in technology is making us all behave as though we had our brains amputated."*

All positive, no negative feedback, in other words. And positive feedback alone just signals "more"; it is the negative feedback that signals "enough," or "too much."

This has to be a cybernetic, or feedback control system. And if it is on a human scale, we must have rational, purposeful controls--decisions and solutions rather than just outcomes, as in simpler ecosystems. Earlier this year, Dr. DuBridge (13) addressing a conference on this subject said "...social controls over applied science do exist and will always exist...they are there - in a variety of forms and with a variety of objectives. The question is: -- Are they--the right forms and do they aim at the right objectives?" A good question.

If there is to be control, there has to be a functioning and purposeful negative feedback loop that does certain things: It senses and measures the output of the system, signals the results to some mechanism for comparing the results with the goals established for the system, notes any discrepancies, and then signals corrective action to those points in the system that can alter the output or whatever it is that the system is doing. This, it seems to me, is the model to use in looking at technology and our environmental crisis.

Now, this kind of thinking is characteristic of a new hybrid discipline which is coming to be identified as a "systems science" in its own right. It is often confused with computer applications and a great many other near and distant activities, but in its

development in the "general systems" theories of von Bertalanffy (14) and others, it may become the ultimate integrator of science and human affairs. Based partially on the original contributions of the ecosystem concept, this broader kind of "systems" thinking may now even be familiar to more non-ecologists than ecologists. The "systems approach" version of it, which has been tainted with Defense Department controversy, is effectively described in a recent book by Churchman (15), with that title. The phrase "systems analysis" is also becoming commonplace, but unfortunately, one cannot be sure what is intended until one has questioned the user about his definitions and purposes.

We know what Eugene Odum (16) means, though, when he uses it in this context:

> *"Although...we readily recognize that we can have too many dams or other large-scale environmental changes, governments are so fragmented and lacking in systems-analysis capabilities that there is no effective mechanism whereby negative feedback signals can be received and acted on before there has been a serious overshoot.*
>
> *"Society needs, and must find as quickly as possible a way to deal with the landscape as a whole, so that manipulative skills (that is,*

> *technology) will not run too far ahead of*
> *our understanding of the impact of change."*

By now my own bias must be visible. I think ecology as a biological science is running interference on this play, but it can't do the scoring. Man's environmental--and other social problems for that matter--demand a kind of unified, integrated attention that no existing discipline or simple combination of disciplines can supply. The imminent emergence of a new systems science does hold promise for meeting the needs for a more comprehensive, scientific basis for public policy making. But it holds threats to our established ways of doing business, too. Our systems approach calls for much more effective planning, and implies the existence of identifiable goals as well as the feedback mechanisms. Where do we find them? Much more progress needs to be made in this ambiguous area.

There is a rapidly developing new field known as systems ecology. If this grows in the directions typified by some of the recent work by Kenneth Watt (17) and others, ecologists will find that they do have common grounds, not only for communication, but for effective interaction with, and perhaps even guidance of, economists, engineers, and the other participants in decision-making systems, including profit-seeking private industry.

Bertrand Russell once said something like this:

> *"We usually appeal to nobler motives to accomplish the very things that calculated selfishness would dictate, if only the calaulations were correct."*

Can ecology make the calculations correct? Ecologists, as scientists, can help by merely reporting their authentic information, as called for by the traditional scientific method. But will they respond to Pierre Dansereau's (18) appraisal that "We...are on the threshold of a new era in which we shall have to redefine our terms and our task."

Will they join individuals from the other disciplines with a toe-hold in environmental problems, cross old boundaries, and extend their scientific abilities and influence into the actual decision process through a much broader and deeper systems approach? Ecologists can deal with large comprehensive systems as well as their own ecosystems, once they learn how. It is being done, from many directions. Ian McHarg is an example from another field.

Or will they prefer to retain their professional purity, hope their data will be used, and try to save the world on their own time? I'm optimistic, but let's not forget Dansereau's gentle reminder: "No, my dear ecologists, our task is not done."

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   "... I have noticed a tendency--less among the theorists than among the practical experts--to make a distinction between economic and noneconomic values. This distinction has been made both in the evaluation of benefits and in the evaluation of costs or opportunities forgone. I submit that this is a mistake. We must not put 'economic values' to one side and other values--say, ethical, aesthetic, social, political, or 'human'--to the other side. The economic valuation of benefits and costs of an institution, plan, or activity must attempt to take account of values of any sort and to apply reasoned argument and rational weighting to problems commonly approached only by visceral emoting.

   "We shall still have to distinguish between pecuniary and nonpecuniary advantages and disadvantages, and between judgments that rest on statistical records and others that are purely subjective evaluations without any supporting numerical data. But the point to note is that economic evaluation is not confined to the items for which price data are available. It comprises all pros and cons of the plan or activity under examination.

> "Cost-benefit analysis is not only used for governmental decision-making; it is applicable, and indeed regularly applied, to private decisions, in business as well as in personal affairs. When one of us considers changing his job--from one university to another, or from an academic to a government setting--he compares pecuniary and nonpecuniary advantages and disadvantages. In his list of pros and cons will appear not only the immediate salary difference and the probability of future salary increases, but also other pecuniary items, such as differences in living cost, especially cost of housing, and the expenses of moving. And there will be nonpecuniary items, such as his wife's miseries and gripes about losing old friends and meeting new people, the childeren's attitudes about changing schools and playmates, the better or worse opportunities to attend concerts and theaters, the inconvenience of moving books and placing them on new shelves, the loss of time in getting resettled, and so forth.
>
> "All these and many other things enter into the considerations; all the items, including the pleasure of a better orchestra and the pain of hurting old colleagues, are part of the economic valuation of the total package of costs and benefits. It is very helpful to spell out all the items and attach a numerical value to each. If some one tells me he will not move, because he cannot bear to hurt his department chairman or because he cannot give up his partners at bridge or chamber music, I am inclined to ask him whether this is worth $5,000 a year to him, or only $3,000 a year. Quantification of nonmeasurable values is often necessary for rational decision-making."

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